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European Refuse Fired Energy Systems: Evaluation of Design Practices. Volume XI: Co-Disposal Refuse and Sewage Sludge Plants, Dieppe and Deauville, France

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EUROPEAN REFUSE FIRED ENERGY SYSTEMS

EVALUATION OF DESIGN PRACTICES

Co-Disposal Refuse and Sewage Sludge Plants
Dieppe and Deauville, France

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Volume 11

U.S. ENVIRONMENTAL PROTECTION AGENCY

1979

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An environmental protection publication (SW-176c.11) in the solid waste management series.

TRIP REPORT

to

DIEPPE (AND DEAUVILLE), FRANCE, PLANTS COFIRING REFUSE AND SEWAGE SLUDGE

on the contract

EVALUATION OF EUROPEAN REFUSE-FIRED STEAM GENERATOR DESIGN PRACTICES

September 20-22, 1977

to

U.S. ENVIRONMENTAL PROTECTION AGENCY

February 15, 1978

EPA Contract No. 68-01-4376
EPA RFP No. WA-76-B146

by

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PREFACE

This trip report is one of a series of 15 trip reports on European waste-to-energy systems prepared for the U.S. Environmental Protection Agency. The overall objective of this investigation is to describe and analyze European plants in such ways that the essential factors in their successful operation can be interpreted and applied in various U.S. communities. The plants visited are considered from the standpoint of environment, economics and technology.

The material in this report has been carefully reviewed by the European grate or boiler manufacturers and respective American licensees. Nevertheless, Battelle Columbus Laboratories maintains ultimate responsibility for the report content. The opinions set forth in this report are those of the Battelle staff members and are not to be considered by EPA policy.

The intent of the report is to provide decision making information. The reader is thus cautioned against believing that there is enough information to design a system. Some proprietary information has been deleted at the request of vendors. While the contents are detailed, they represent only the tip of the iceberg of knowledge necessary to develop a reliable, economical and environmentally beneficial system.

The selection of particular plants to visit was made by Battelle, the American licensees, the European grate manufacturers, and EPA. Purposely, the sampling is skewed to the "better" plants that are models of what the parties would like to develop in America. Some plants were selected because many features envolved at that plant. Others were chosen because of strong American interest in co-disposal of refuse and sewage sludge.

The four volumes plus the trip reports for the 15 European plants are available through The National Technical Information Service, Springfield, Virginia 22161. NTIS numbers for the volumes and ordering information are contained in the back of this publication. Of the 19 volumes only the Executive Summary and Inventory have been prepared for wide distribution.

ORGANIZATION

The four volumes and 15 trip reports are organized the the following fashion:

VOLUME I

A EXECUTIVE SUMMARY
B INVENTORY OF WASTE-TO-ENERGY PLANTS
C DESCRIPTION OF COMMUNITIES VISITED
D SEPARABLE WASTE STREAMS
E REFUSE COLLECTION AND TRANSFER STATIONS
F COMPOSITION OF REFUSE
G HEATING VALUE OF REFUSE
H REFUSE GENERATION AND BURNING RATES PER PERSON
I DEVELOPMENT OF VISITED SYSTEMS

VOLUME II

J TOTAL OPERATING SYSTEM RESULTS
K ENERGY UTILIZATION
L ECONOMICS AND FINANCE
M OWNERSHIP, ORGANIZATION, PERSONNEL AND TRAINING

VOLUME III

P REFUSE HANDLING
Q GRATES AND PRIMARY AIR
R ASH HANDLING AND RECOVERY
S FURNACE WALL
T SECONDARY (OVERFIRE) AIR

VOLUME IV

U BOILERS
V SUPPLEMENTARY CO-FIRING WITH OIL, WASTE OIL AND SOLVENTS
W CO-DISPOSAL OF REFUSE AND SEWAGE SLUDGE
X AIR POLLUTION CONTROL
Y START-UP AND SHUT-DOWN
Z APPENDIX

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LIST OF PERSONS CONTACTED

M. Jean Fossey	Dieppe Plant Manager
M. Bernard Montdesert	Dieppe Plant Chief Engineer
M. Aime Marchand	Director, General des Services techniques, Dieppe
M. Hervee	Asst. Manager, Deauville Plant
Beat C. Ochse	Project Engineer, Von Roll, Ltd., Environ. Eng. Div., Zurich
John M. Kehoe, Jr.	Vice President and General Manager, Wheelabrator-Frye, Inc., Energy Systems Div., Hampton, N.H.
David B. Sussman	Project Monitor, U.S. EPA, Resource Recovery Div., Washington, D.C.

The authors are pleased to acknowledge the considerable assistance provided by the above individuals in the conduct of this visit and in subsequent review of this report.

SUMMARY

Although the Dieppe and Deauville plants are small, 120 metric tons per day each, and do not use water-tube-wall boiler construction, they are examples of a relatively new waste-to-energy system in which the steam generated by burning refuse under very simple fire-tube boilers is used in a patented system to dry sewage sludge in steam-heated, thin-film dryers. When dried, the sludge then becomes a low-energy fuel. Thus, these systems provide all of their own energy to dispose of both community refuse and sludge in an environmentally clean manner.

The two plants are identical in many respects. However, they differ significantly in three ways:

(1) The older plant, Dieppe (1971), uses mechanical dust collectors; Deauville has electrostatic precipitators. Although the Dieppe emissions meet current local standards, the newer Deauville plant (1976) is equipped to meet possibly more stringent regulations of the future.

(2) The Dieppe furnaces employ a sloping water-cooled baffle in the furnace, the Deauville furnaces are open and not baffled

(3) Dieppe uses two LUWA thin-film dryers for sludge but Deauville relies on the high availability of one, larger dryer of the same type.

STATISTICAL SUMMARY--DIEPPE ONLY

Community Description:	
Area (square kilometers)	60
Population (number of people)	48,000
Key terrain feature	Hilly
Solid Waste Practices:	
Total waste generated per day (tonnes/day)	50
Waste generation rate (Kg/person/day)	1.3
Lower heating value of waste (Kcal/kg)	--
Collection period (days/week)	5
Cost of collection (local currency/tonne)	--
Use of transfer and/or pretreatment (yes or no)	No
Distance from generation centroid to:	
Local landfill (kilometers)	--
Refuse-fired steam generator (kilometers)	2
Waste type input to system	Resid., Indus.
Cofiring of sewage sludge (yes or no)	Yes
Development of the System:	
Date operation began (year)	1971
Plant Architecture:	
Material of exterior construction	Concrete, Steel
Stack height (meters)	35
Refuse-Fired Steam Generator Equipment:	
Mass burning (yes or no)	Yes
Waste conditions into feed chute:	

STATISTICAL SUMMARY--DIEPPE ONLY

Moisture (percent)	--
Lower heating value (Kcal/kg)	--
Volume burned:	
Capacity per furnace (tonnes/day)	60
Number of furnaces constructed (number)	2
Capacity per system (tonnes/day)	120
Actual per furnace (tonnes/day)	63
Number of furnaces normally operating (number)	1
Actual per system (tonnes/day)	63
Use auxiliary reduction equipment (yes or no)	No
Pit capacity level full:	
(tonnes)	--
(m^3)	750
Crane capacity (one):	
(tonnes)	4.25
(m^3)	1.5
Feeder drive method	Hydraulic
Burning grate:	
Manufacturer	Van Roll
Type	Reciprocating
Number of sections (number)	2
Length overall (m)	8
Width overall (m)	2
Primary air-max (Nm^3/hr)	19,440
Secondary air-overfire air-max (m^3/min)	83
Furnace volume (m^3)	80
Furnace wall tube diameter (cm)	No wall tubes
Furnace heating surface (m^2)	--
Auxiliary fuel capability (yes or no)	Yes
Use of superheater (yes or no)	No

STATISTICAL SUMMARY-DIEPPE ONLY

Boiler	
Manufacturer	Sacoma
Type	Vertical
Firetube	
Number of boiler passes	1
Steam production per boiler (kg/hr) (max)	7,500
Total plant steam production (kg/hr) (max)	15,000
Steam temperature (^{o}C)	180
Steam pressure (bar)	10
Use of economizer (yes or no)	No
Use of air preheater (yes or no)	Yes
Use of flue gas reheater (yes or no)	No
Cofire (fuel or waste) input	Yes
Use of electricity generator (yes or no)	No
Energy Utilization:	
Medium of energy transfer	Steam
Temperature of medium (^{o}C)	180
Population receiving energy (number)	Sludge Drying Only
Pressure of medium (bar)	10
Energy return medium	--
Pollution Control:	
Air:	
Furnace exit conditions:	
Gas flow rate (Nm^3/hr)	22,000
Furnace exit loading (mg/Nm^3)	--
Chimney particulate emission (mg/Nm^3)	320

OVERALL SYSTEM SCHEMATIC

Figure 10-1 shows a diagram of the Dieppe plant. As will be seen throughout this report, the Deauville plant is not identical but is similar to Figure 10-1 in many ways. The Dieppe refuse plant was started up in November, 1971, the wastewater plant in February, 1971. The Deauville refuse plant began regular operation in early 1976.

OVERALL SYSTEM SCHEMATIC

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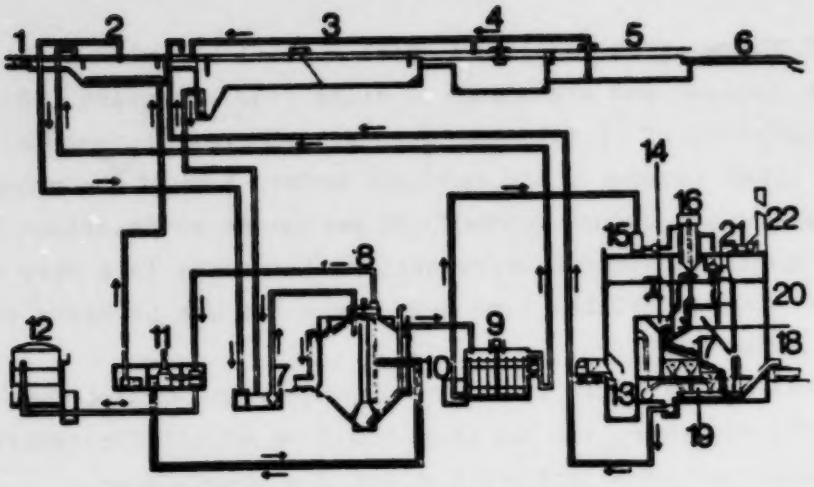


1. Wastewater inlet meter
2. Grit-oil separator
3. Primary settling basin
4. Aeration tank
5. Secondary settling basin
6. Discharge water
7. Raw sewage pump
8. Digester
9. Thickener
10. Sludge pump
11. Digester heater-pumps-gas meter
12. Gas holder
13. Refuse bunker
14. Refuse feed hopper
15. Sludge tank
16. Vertical thin-film dryer
17. Incineration grates
18. Waste oil burner
19. Quench channel for residue
20. Boiler
21. Dust collector
22. Chimney

FIGURE 10-1. OVERALL SCHEMATIC DIAGRAM OF THE DIEPPE PLANT FOR COMBINED PROCESSING OF COMMUNITY WASTEWATER AND REFUSE

COMMUNITY DESCRIPTION

Both Dieppe and Deauville are small resort towns with beaches on the English channel and are about 70 miles (110 km) apart . Dieppe, permanent population of 26,000, has been an important industrial port since Roman times because of its excellent harbor, "one of the safest and deepest harbors on the English Channel". It has become an important port, rail, and industrial manufacturing center. Deauville is a very clean seaside resort town on rolling land near Trouville and Le Havre at the mouth of the Seine.

It was natural that in order to preserve and enhance the resort feature of their existence, the two towns would be especially interested in handling their wastewater and solid wastes in a clean manner.

Solid waste at the Dieppe plant is received from a 12 km (7 mi) radius area which includes Neuville and five other villages and many industries in very hilly terrain. The total population served is about 48,000. Approximatey 10 percent of the refuse received is industrial. Unique waste at the rate of 1.5 tonne/day comes as fiberglass, resin, and paint wastes from the Renault Alpine Sportscar Body Factory. The paint comes in 25 kg (55 lb) plastic bags. Vinyl upholstery scraps did come from a local plant but if too much is charged at once, it melts and clogs the grate; hence, the amount of this material accepted had to be limited.

In Deauville (permanent population at 6,000) is surrounded by adjacent communities with a permanent population of 20,000. However, in the summer the wastes from 200,000 vacationers on a typical summer day must be processed. There is no industrial waste in Deauville.

SOLID WASTE PRACTICES

The total solid waste received at Dieppe is about 19,000 tonnes/yr (20,900 tons/yr), of which about 10 percent is industrial. Sewage sludge handled is f om 40,000 inhabitants, a rate of about 5,500 m^3/day (1,903,000 gal/day) of digested sludge. The total receipt at Deauville is unknown but because of the 10-fold increase in population served during the few summer months, many difficult and variable operating problems are posed for the plant staff.

At both plants in summer, there is a marked increase in empty seashells from kitchen wastes.

Collection

For the Dieppe-Neuville area, there are eight city collection trucks plus three small open trucks which, until October 1, 1977, collected daily 6 days per week. After October 1, 1977, collections were to be every 2 days. Other suburbs also send in truck loads irregularly, and on Sunday mornings special collections are made from restaurants. The past practice of picking up and dumping open bins at the collection point was to be replaced October 1 by use of polyvinyl chloride bags provided by the city.

Each household and business receives a separate charge on their tax bill for refuse and sewage service which is based at their metered water consumption.

No bulky refuse is accepted at Dieppe larger than 1 meter (3.3 ft).

Solid Waste Disposal

Landfill is used for the combustion residue from Dieppe and for bulky and demolition waste. Some industrial waste is collected by a private contractor, shredded, and then landfilled. The city makes no charge for use of the landfill.

Sewage Treatment

At both plants, Dieppe and Deauville, the waste burning plant is adjacent to the modern sewage plant so that the energy released as steam from the burning of refuse can be utilized in partially drying the digested sludge which then can be disposed of by burning with the solid waste.[1,2]

At Dieppe, the wastewater from a population of about 40,000 and at a flow rate of about 5,500 m^3/day (1,903,000 gal/day) is clarified, aerated, digested for 30 days, and chlorinated in the following steps:

	Volume	
	m^3	gals
Primary Clarification Basin	950	328,700
Agitated Aeration Tank	815	281,990
Secondary Decanters	1,050	363,300
Digester	1,250	432,500
Thickener	280	96,880
Chlorination Basin	108	37,368

The water discharged from this system has a BOD of about 30 except in the mornings when discharges from the local abattoir raise the final BOD to 45.

Dieppe's sludge at about 96 percent water content is piped to two steam-heated, thin-film dryers in the refuse plant where it is dried to about 48 percent water and then burned as described later. At Deauville, there is only one sludge dryer.

Methane-rich gas, collected from the digester, is stored in a 125 m^3 (4,412 ft^3) gas holder. The 64 percent methane-rich gas is burned to maintain the digester temperature at 80 C (176 F) and to provide space heating in the plant and offices. The gas production rate is about 500 m^3/day (17,650 ft^3/day).

DEVELOPMENT OF THE SYSTEM

Prior to the construction of the Dieppe plant in 1970-1971, the city and surrounding communities deposited their solid wastes in various uncontrolled landfills. Sewage treatment begun in 1934 was by primary settling only. Because of smokey fires at the landfills and the growing scarcity of available landfill area, discussions began in city council late in 1967 on feasible means to upgrade their waste management methods.(2) Composting was considered but not pursued because of the lack of assured local markets for the product. District heating was considered but only two factories in the vicinity could have used the steam. Electricity generation was discussed but Electricite de France could not guarantee revenue for the electricity produced.

M. Jean Fossey, who is now plant manager, was, at the time of the discussions, a member of city council. M. Marchand, then Director General of Technical Services for the City of Dieppe, became interested in the patented process developed by Von Roll, Ltd. This process uses the heat in steam from waste-fired boilers to partially dry sewage sludge in vertical thin film dryers and then to burn the sludge with the refuse. A decision was made in November, 1968, to build a steam generating refuse burner to begin operation in about 18 months or about May, 1970. Also, in April, 1969, it was decided to build, adjacent, a modern wastewater treatment plant to begin operation about April, 1971. The plants were sized for a community of about 48,000 people producing refuse and 40,000 people producing sewage. INOR S. A. (Societe de Construction d'Usines d'Incineration d'Ordures Menageres), the Von Roll licensee in France for this type of combined system, was selected to build them. Because it was the first full-scale combined plant of this type, Von Voll offered it at an introductory price.

On the strength of the decision at Dieppe in 1969 to build this pioneering plant, the city of Brive in southern France, population 55,000, invited bids on a combined facility in late 1969. By December, 1970, eight qualified bids had been received at Brive. In July, 1971, INOR S. A. was

awarded a contract for the refuse burner and ODA (Omnium d'Assainissement), a French water treatment firm, was given the contract for the wastewater plant. The Brive refuse burner began operating in September, 1973, 2 years after the Dieppe plant and the wastewater plant in February, 1975.

The plants are operated for the city under a 20-year contract with the group Thermical-INOR.

The prospect for clean handling of both solid and liquid wastes at Dieppe and Brive probably were an important guide to Deauville, which decided to follow suit. The new Deauville facility was built on the site of the old city sewage treatment plant. The Deauville wastewater plant began operating in 1974 and the refuse burning plant early in 1976.

PLANT ARCHITECTURE

The two Dieppe plants are located together in an industrial zone on the site of an old landfill unused for 15 years along the small river of Arques, about 2 km (1.3 mi) south of Dieppe. The site occupies 1.7 hectares (4.2 acres), about 3 or 4 m (7 to 13 ft) above sea level. Because of the alluvial nature of the river valley and the site's history as a landfill, 152 concrete piles, about 16 m (52 ft) deep had to be installed to support the waste-burning structure and equipment. The building walls and pit walls are relatively thin to minimize the total weight on the piling.

Figure 10-2 shows the Dieppe waste-burning plant. It is partly made of cellular concrete to minimize weight plus metal panels supported on a steel structure. It is 26 m (85 ft) tall. The chimney is 35 m (115 ft) tall.

Figure 10-3 shows the Deauville plant which is also formed of concrete and coated steel panels and located on a gently sloping hillside. Inside and outside it is an unusually attractive plant with bright colors used to give emphasis to the various types of equipment.

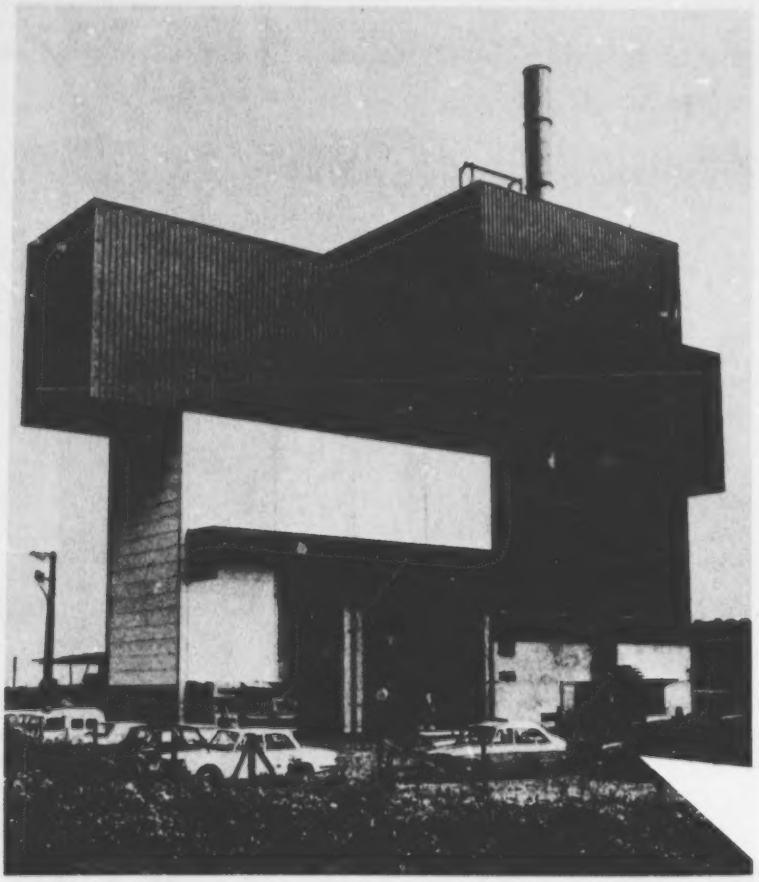


FIGURE 10-2. DIEPPE REFUSE-SLUDGE COFIRING PLANT
(COURTESY VON ROLL, LTD.)

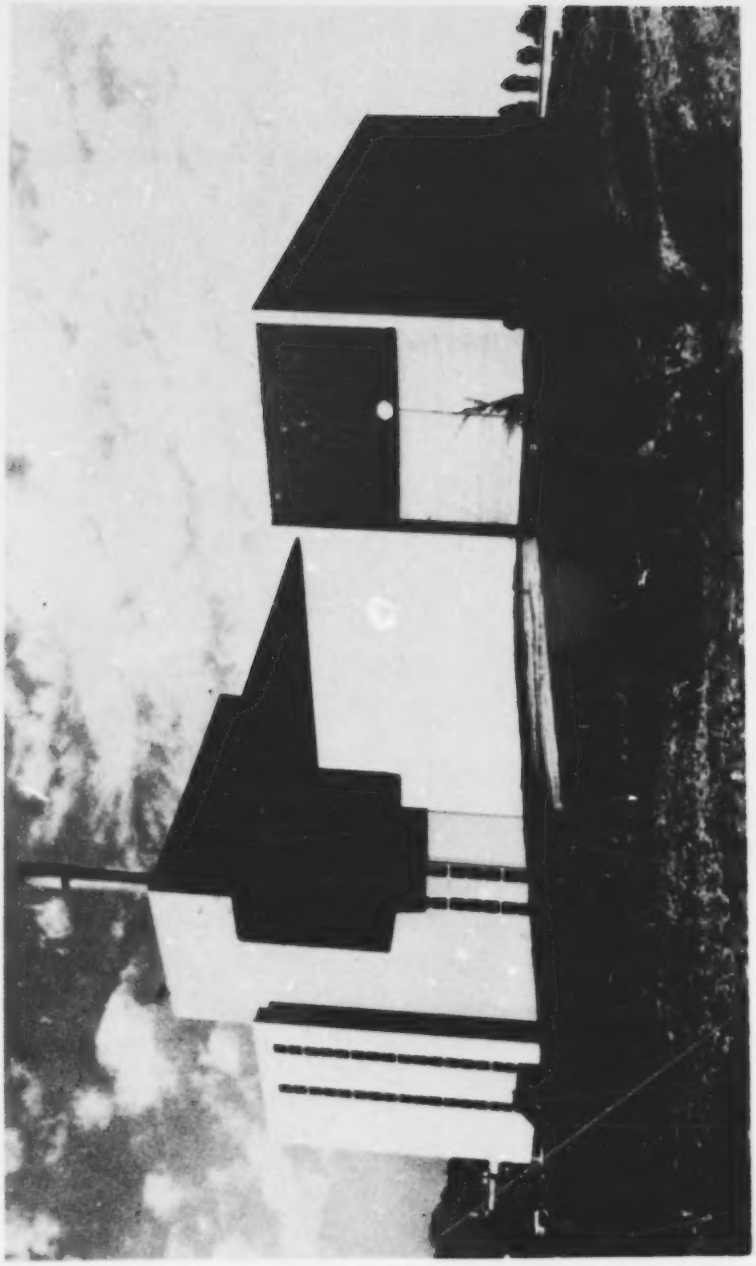


FIGURE 10-3. DEAUVILLE REFUSE-SLUDGE COFIRING PLANT
(COURTESY OF INOR S.A.)

REFUSE-FIRED STEAM GENERATING EQUIPMENT

Waste Input

The Dieppe plant receives principally household waste plus some industrial waste. No waste is accepted larger than 1 m (3.3 ft), and there is no shear or other pretreatment. Refuse is delivered on public and private vehicles on weekdays from 8:00 to 11:00 a.m., and from 2:00 to 5:00 p.m. One man is assigned to operate the scale.

Table 10-1 shows the results of analysis of two typical samples of refuse received in 2 winter months of 1975.

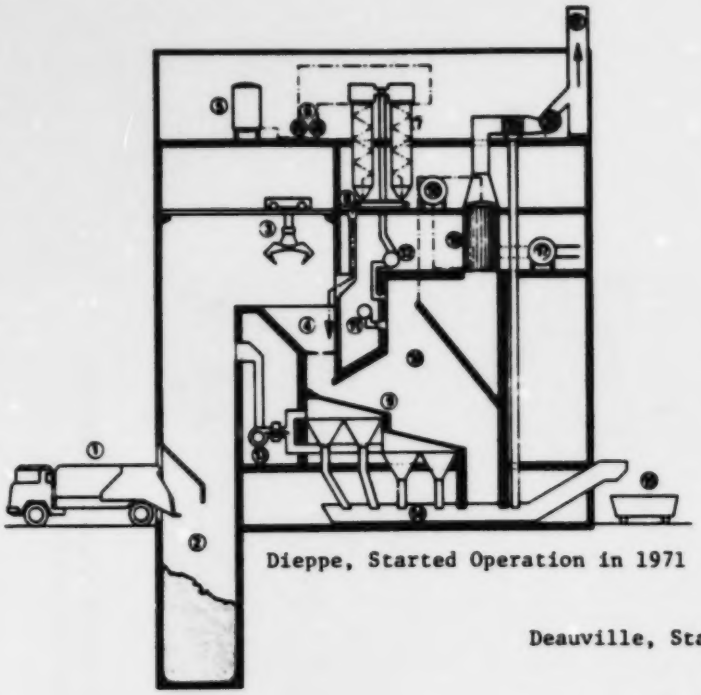
Figure 10-4 shows cross sections of the Dieppe and Deauville refuse-burning plants.

The Dieppe plant pit has a capacity when level full at 750 m^3 (26,475 ft^3). Above the pit is a single 4.25 tonne (4.7 ton) crane, built by Reel, carrying a 1.5 m^3 (53 ft^3) clam shell bucket. The Deauville pit capacity is 700 m^3. At both the Dieppe and Deauville plants, the crane is controlled from the control room, a common feature to minimize manpower needs at small plants in Europe. Figures 10-5 and 10-6 show the control rooms.

At Deauville, it has been found that lack of a spare crane is a distinct disadvantage when crane repairs are needed during the summer period, when maximum operation is needed. At Dieppe, the crane cables needed replacement after 1 year due to numerous startup problems in learning to operate the crane in such a way as to minimize cable damage. The new cables, made by Casar especially for the Dieppe plant, are automatically lubricated and are formed of thick wires inside and finer ones outside which are wound alternately in opposite directions to avoid twisting.

TABLE 10-1. APPROXIMATE COMPOSITION OF TWO SAMPLES OF REFUSE RECEIVED AT DIEPPE IN 1975 (COURTESY OF THERMICAL-INOR)

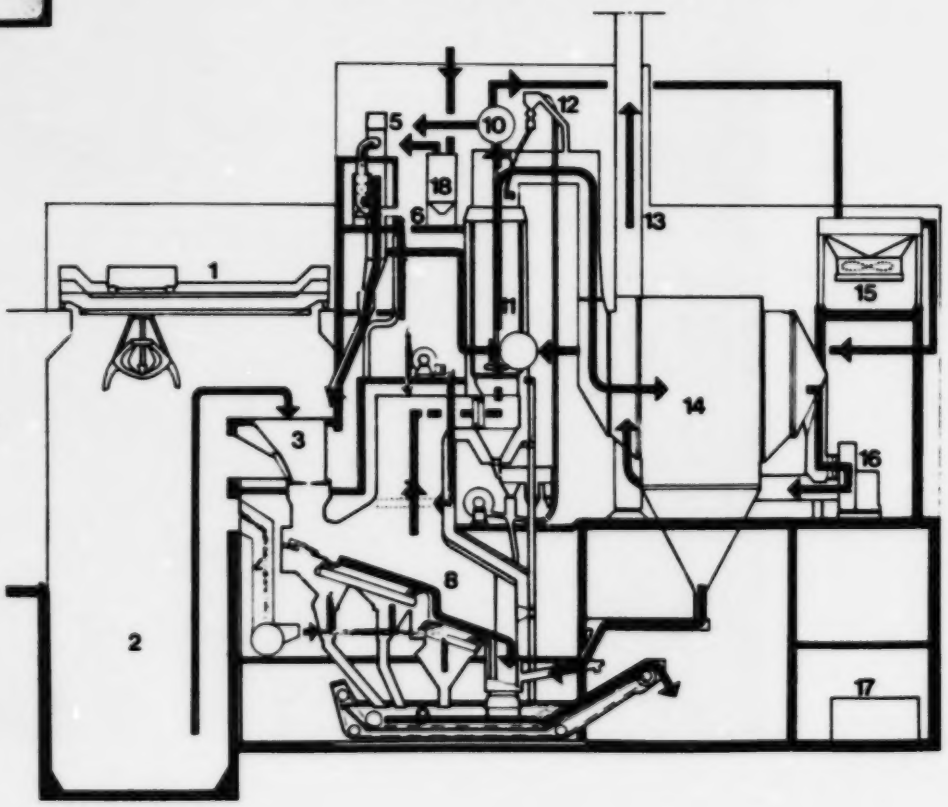
	Sample for February 3, 1975		Sample for December 4, 1975	
	Weight, Percent	Moisture, Percent	Weight, Percent	Moisture, Percent
Fines, Unidentified Pieces smaller than 2 mm	25.30	41.1	31.90	16.7
Paper Cartons	5.97	25.9	9.90	15.2
Cloth	0.20	44.5	0.90	28.1
Plastics	3.50	11.2	1.20	9.8
Bones	0.65	15.6	0.45	15.4
Metal	4.60	3.8	2.90	3.7
Glass	9.85	5.1	5.20	3.2
Unclassified Combustibles	4.25	13.4	2.70	18.3
Unclassified Inerts	17.22	8.0	15.20	6.1
Putrescibles	28.46	83.6	29.65	78.8



1. Outdoor tipping area
2. Refuse pit
3. Crane and bucket
4. Feed hopper
5. Sludge storage tank
6. Sludge pumps
7. Sludge dryers
8. Dried sludge conveyor
9. Incineration grates
10. Furnace
11. Oil burner
12. Blower for dryer vapors
13. Primary air blower
14. Residue quench channel
15. Residue cart
16. Boiler
17. Water-cooled condenser
18. Steam drum
19. Dust collector
20. Induced draft fan
21. Chimney

Dieppe, Started Operation in 1971

Deauville, Started Operation in 1976



1. Crane
2. Refuse bunker
3. Feed hopper
4. Water storage
5. Sludge dryer
6. Dryer exhaust blower
7. Secondary air blower
8. Furnace
9. Residue quench channel
10. Steam drum
11. Boiler
12. Shot cleaning feeder
13. Chimney
14. Electrostatic precipitator
15. Air-cooled condenser
16. Induced draft fan
17. Transformer room
18. Sludge storage

FIGURE 10-4. COMPARATIVE CROSS SECTIONS OF DIEPPE AND DEAUVILLE REFUSE-BURNING PLANTS (COURTESY OF CITIES OF DIEPPE, DEAUVILLE, AND VON ROLL, LTD. AND INOR S.A.)

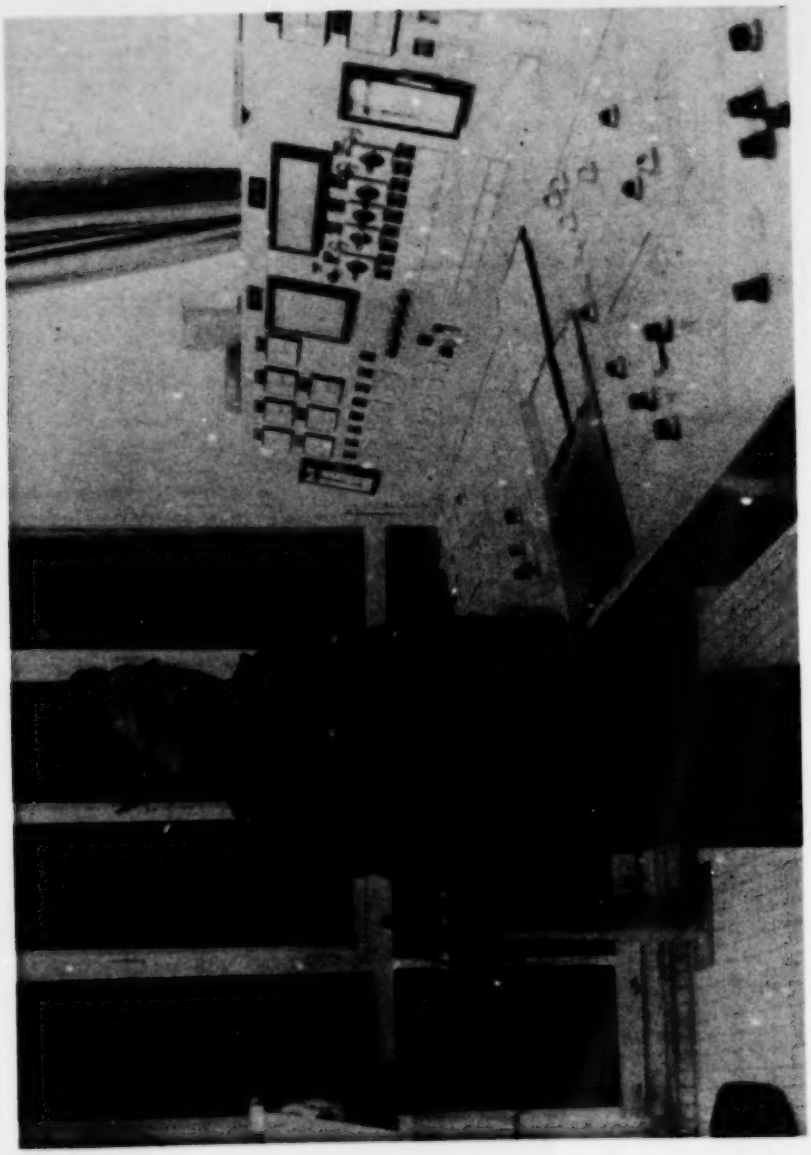


FIGURE 10-5. DIEPPE CONTROL ROOM WITH CRANE CONTROL PEDESTAL AT REAR AT WINDOW OVERLOOKING REFUSE PIT (Battelle Photograph)

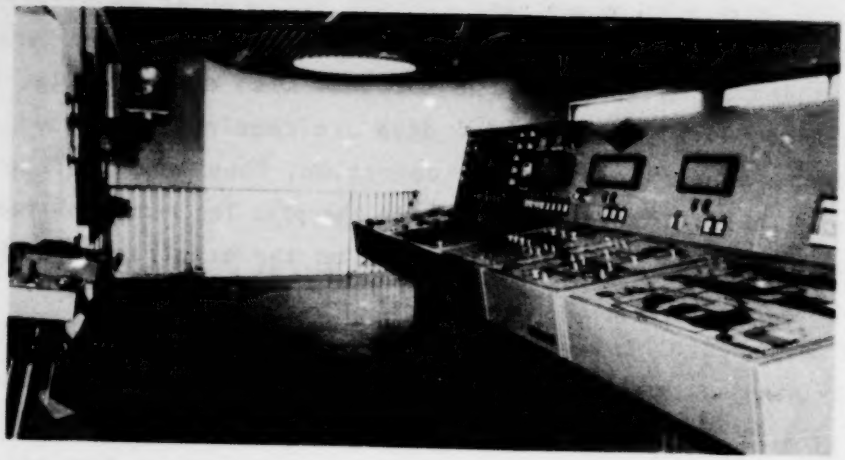


FIGURE 10-6. DEAUVILLE CONTROL ROOM. THE CRANE CONTROL PEDESTALS AT LEFT ARE AT A LARGE WINDOW OVERLOOKING THE REFUSE PIT (COURTESY INOR, S.A.)

At Dieppe, the crane lifts a load and automatically positions the bucket above one or another of the two furnace hoppers. At Deauville, a similar automatic control system has been temporarily by-passed because the bucket damaged a railing near the hoppers. Also at Deauville, the winter load is so light that several days are required to accumulate enough refuse to support one furnace operation. Thus, some refuse is stored so long that fermentation begins in the pit. The resultant vapors generated are corrosive when they condense on the electrical control contacts which has caused control failures.

The lightweight cellular concrete pit walls at Dieppe are reinforced by steel columns to withstand occasional impact from the loaded bucket.

At Dieppe, there are five temperature sensors at door height, above the pit to detect pit fires. Small pit fires are handled by using the clam shell bucket to lift the burning material into one of the furnace hoppers. Larger fires are controlled by internal or external (city) fire-fighting equipment. When a temperature sensor detects a temperature rise, it actuates a recording which announces, "There is a fire in the pit".

The procedure for starting a fire in a furnace at Dieppe is to ignite the bucket load of highly combustible refuse, drop it into the furnace hopper, and then feed it onto the grate by opening the horizontal flap doors at the bottom of the hopper. Once a fire erupted in a hopper when 600 kg (1,320 lb) of butter was charged at once. Well mixed with other refuse, it would have caused less problem.

Furnace Hoppers

As seen in Figure 10-4, the hoppers at both plants are similar, 2 m by 4 m (6.5 by 13 ft) at top and at the base of the chute, the dimensions are 1.6 m by 1.2 m (5.2 by 4 ft), with the juncture between hopper and chute sealed by a flap damper to prevent burnback. This method of feeding and sealing is impractical for much larger plants where Von

Roll uses a vibrating feeder to feed from the chute to the furnace. At both plants, the chute is water jacketed but a thermocouple in the jacket at Deauville indicates that water flow to the jacket for cooling is seldom needed. Some wet-type corrosion was visible on the jackets.

Although as shown in Figure 10-4, at Dieppe, the refuse appears to fall directly on the main burning grate, actually there is the same arrangement as at Deauville where a reciprocating type of feeder has been placed in the furnace to feed the main burning grate. There is no combustion air supplied to the feeder.

Grate

The grate used at Dieppe is the older Von Roll design using alternately reciprocating parallel sections. The material is nickel-chromium cast iron. Feed capacity is 3 tonnes/hr (3.3 tons/hr) maximum, 2.8 tonnes/hr normal. The total grate is 2 m wide and a total of 8 m long in two steps. Steam-preheated air is used at both plants. There are two air zones under each step, a total of four zones.

About one half of the Dieppe grate has been replaced in 7 years. Some worn main grate bars can be moved to the burnout grate for less strenuous service. Because of the moderate rate of receipt of refuse at Dieppe, only one furnace is operated at a time, leaving ample time for grate maintenance. Operation is switched between furnaces about every 3 weeks. There has not been any grate blockage by melted material and neither grate has been cleaned for 3 years. The unburned carbon content of the residue ranges from 3 to 4 percent except when large amounts of moist waste such as grass cuttings are burned. Grate wear is thought to be accelerated by the relatively high proportion of sea shells in the refuse during summer months.

There is no separation of ferrous or other material from the quenched grate residue.

Furnace Wall

There are two major reasons why the relatively new Dieppe and Deauville furnaces are not water-tube walled:

(1) The burning of only partially dried sewage sludge has a cooling effect in the furnace; hence, extensive wall cooling is not needed.

(2) The steam generated for heating the sludge dryers needs to be at only moderate pressure; hence, a much simpler refractory wall furnace and cheaper firetube waste heat boiler can be used.

Accordingly, the only furnace cooling at Dieppe is the diagonal furnace baffle shown in Figure 10-4. This baffle is formed of spaced, sloping tubes about 120 mm (4.7 in) apart, which supports bricks shaped to fit the tubes. An estimated 100-150 C (180-170 F) gas temperature drop occurs as the gases flow upward along the underside of the sloping baffle then pass through the spaced tubes above the baffle and turn toward the vertical firetube boiler inlet. It is estimated that about one sixth of the total heat is absorbed by the baffle.

As the gases turn downward around the top of the baffle, they decelerate causing the larger flyash particles to fall out and deposit on the sloping baffle. The buildup of such deposits causes the top-side cooling surface to become ineffective. Also, removal of the accumulated deposit has been difficult. The top and bottom headers for the tubes in the furnace baffle are studded with 40 mm (1.6 in) studs and covered with 80 mm (3.1 in) of Plibrico castable refractory.

At Deauville, designed about 5 years later, there is no water-cooled baffle. The furnace volume is also much less than at Dieppe, which is about 80 m^3 (2,823 ft^3), and the furnace gases at Deauville pass directly to the vertical firetube boiler.

The main furnace wall at both plants is 500 mm (1.6 ft) thick and is enclosed in a 3 mm thick outer steel casing to minimize infiltration of air. The fireside portion of the wall is built of 65 percent alumina

brick. No bricks have had to be replaced except one row of brick in the nose of the front arch after 5 year's operation. Occasionally, broken bricks are patched with Plibrico plastic refractory rammed into place. Explosions of some types of refuse cause some refractory damage and push water out of the clinker quench channel under the furnace. Occasionally, some of the formed bricks in the water-cooled sloping baffle need to be replaced.

The use of refractory instead of water-tube walls entails some loss of thermal efficiency but this loss is not important at either plant so long as there is ample steam generated to dry the sludge.

Each furnace has a 6 million calorie/hr oil burner, but they are never used.

Fire-Tube Boiler--Dieppe

The vertical boilers at Dieppe were built by Sacoma with a heating surface of 240 m^2 (2,582 ft^2). They are 6 m (19.7 ft) tall and 1.8 m (5.9 ft) outside diameter. The 387 tubes are 52 mm (2 in) inside. The boilers were designed to produce 7.5 tonne/hr (15,510 lb/hr) of steam at 16 bar (1,600 kPa) 232 psia . The saturated steam temperature is 180 C (356 F). Actually the boilers operate at a pressure of about 10 bar (1,000 kPa) 145 psia and an output of 6.5 tonnes/hr (14,000 lb/hr). Feedwater temperature is 140 C (284 F).

Design gas flow rate was 22,000 Nm^3/hr (12,947 scfm). The flue gas temperature leaving the boiler was about 350 C (662 F) when the plant started up. However, it was found necessary to inject 5,000m^3/hr (2,943 cfm) of secondary air by means of six nozzles located in the front wall. This air diluted the flue gas and caused the boiler exit gas temperature to drop to about 280 C (536 F). Such a high exhaust temperature represents a substantial thermal loss but since there is ample heat for drying the sludge and, at present, no other use for the heat, the loss is not serious for this particular plant.

Every 3 months, each boiler is drained and completely cleaned internally and externally by the plant staff using brushes and other small tools.

Fire-Tube Boiler--Deauville

The Deauville boilers are of the same design, manufacture, and capacity as at Dieppe but the flyash deposits are cleaned from the boiler tubes by falling steel shot pellets which are fed periodically into the top of the boiler. After the shot fall through the tubes, they then fall along with the dislodged ash into a conical hopper situated directly beneath the boiler. The shot are then separated by gravity from the lighter flyash and the shot are recirculated in a high velocity air stream to the top of the boiler for another cleaning cycle.

In addition to this cleaning process, the experience had been that every 10 weeks it was necessary to hand clean persistent ash deposits from the tube surfaces. However, in April, 1977, the staff began regularly to blow into the furnace a fine inorganic dust known as Gamlenite 8 in order to soften the ash deposits in the tubes so that the shot would remove them and hand cleaning would not be necessary. About 2 to 3 kg (4.5 to 6.5 lb) is blown in with air every 2 or 3 hours. According to the staff, this additive has so far been entirely successful in making the tube deposits so friable that they are readily removed by the shot, thus eliminating the need for hand cleaning.

At Deauville, the exhaust gas is continuously monitored for CO content and will later also be monitored for O_2. An opacity meter is unsatisfactory because the readings are in error due to rapid soot accumulation on the instrument window.

Primary Air

At both plants, the combustion air is drawn from above the bunker at a point shown in Figure 10-4 in the inner bunker wall a short distance

below thehoppers. The Sovent centrifugal blowers provide a flow rate of 19,440 Nm^3/hr at 20 C (11,440 cfm at 68 F) at a maximum pressure of 150 mm water (1,471 Pa). It is heated by means of a steam heated heat exchanger to 150 C (302 F).

The negative pressure in the furnace ranges from 15 to 20 mm water (147 to 196 Pa).

Secondary Air

Initially, the Dieppe furnaces were operated without overfire air but later front-wall jets were added, supplied by a blower with maximum capacity of 5,000 Nm^3/hr (2,943 scfm) at 150 mm water (1,470 Pa).

The approximate point of injection of secondary air through six jets in each sidewall at the Deauville plant is shown in Figure 10-4.

Air Preheater

At both plants, the primary air is preheated to about 150 C (302 F) by a steam-air heater made by Favier. At Dieppe, it uses an estimated maximum of 600 kg/hr (1,320 lb/hr) of saturated steam at 190 C (374 F) and can heat up to 16,000 Nm^3/hr (9,416 scfm). The approximate heat exchanger dimensions are 1 m by 1.5 m by 90 mm (3.3 ft by 4.9 ft by 3.5 in), and the heating surface is 252 m^2 (2,712 ft^2). In one of the two heaters at Dieppe, some tubes failed after 5 years, apparently due to a manufacturing defect, and was replaced. There is evidently some erosion of some of the tubes by excessive velocity of the condensing steam; hence, in future modifications, 12 mm (0.5 in) diameter tubes would be replaced by 25 mm (1 in) tubes.

Boiler Water Treatment

At Dieppe, water analysis and treatment is handled by an outside contractor (BEZ), which sends a specialist every 2 months to analyze the water and replenish the treating chemicals. Flow rate through the

feedwater treatment system is 2.5 m^3/hr (865 gal/hr). In March, 1973, the following water analysis results were obtained:

	After Treatment	Feed-Water	Boiler Water	Conden-sate
Oxygen	Trace	0.6	0	0
Alkalinity	0	3	260	1
Total Allkalinity	27	9	298	3
Chloride Ion (mg/l)	17	1	234	0
pH	7.5	9.6	11.7	9.3
P_2O_5	--	--	100	--
N_2H_2	--	--	1,000	--

COFIRING EQUIPMENT

This cofiring system patented world-wide by Von Roll for steam-drying and cofiring sewage sludge with refuse was guaranteed at Dieppe to handle 75 percent refuse and 25 percent dried sludge (by weight). At Dieppe, there are two vertical LUWA dryers about 0.6 m (1.9 ft) inside diameter having a nominal drying capacity of 900 liters/hr (238 gal/hr) of digested sludge having a water content of 92 percent. At Deauville, there is only one larger LUWA dryer having a nominal capacity of 1,100 liters/hr (271 gal/hr). Normally it operates at 900 liters/hr, 24-hours/day in the summer and 4 to 6 hours/day in the winter. Evidently, for the newer Deauville plant, the reliability of the LUWA dryer was deemed such that redundancy was unnecessary. Dieppe was the first to use the LUWA dryer for sewage sludge.

Figure 10-7 shows the two dryers of the LUWA dryer. The inside of the dryer is a smooth stainless steel cylinder having a surface of 5.3 m^2 (57 ft^2) heated to about 180 C (356 F) by saturated steam. The sludge is delivered to the dryers by a dosing pump which sprays it against the hot surface which is rapidly scraped clean by vertical rotating blades attached to a central shaft rotating at 250 rpm. Centrifugal force keeps the boiling sludge against the hot steel surface as the blades force it to rotate. Gravity causes the drying sludge particles to drift downward along the steel heating surface. The product falling from the bottom of the dryer onto a belt conveyor is partially dried sludge agglomerations having 40 to 45 percent moisture. A television camera sighted on the conveyor enables the control room operator to monitor the sludge flow.

The conveyor delivers the granules to a chute leading to the refuse pit from which the crane operator lifts a mixture of refuse and sludge to the furnace hoppers. To eliminate dryer exhaust odor, the wet vapor from the dryers is fed to the upper part of the furnaces. At the Deauville plant, to avoid having droplets returned to the furnace with the

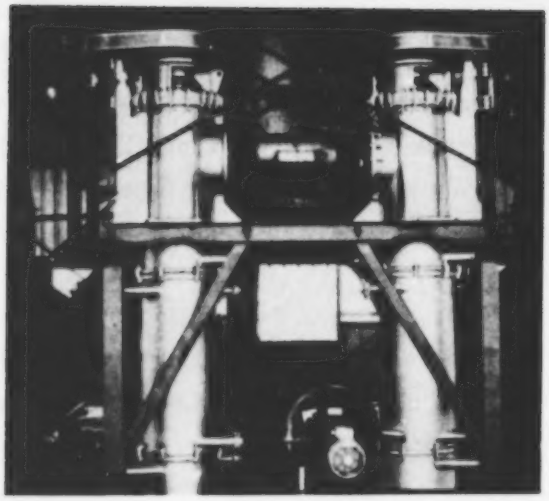


FIGURE 10-7. TOP OF TWO LUWA SLUDGE DRYERS AT DIEPPE (COURTESY OF VON ROLL, LTD.)

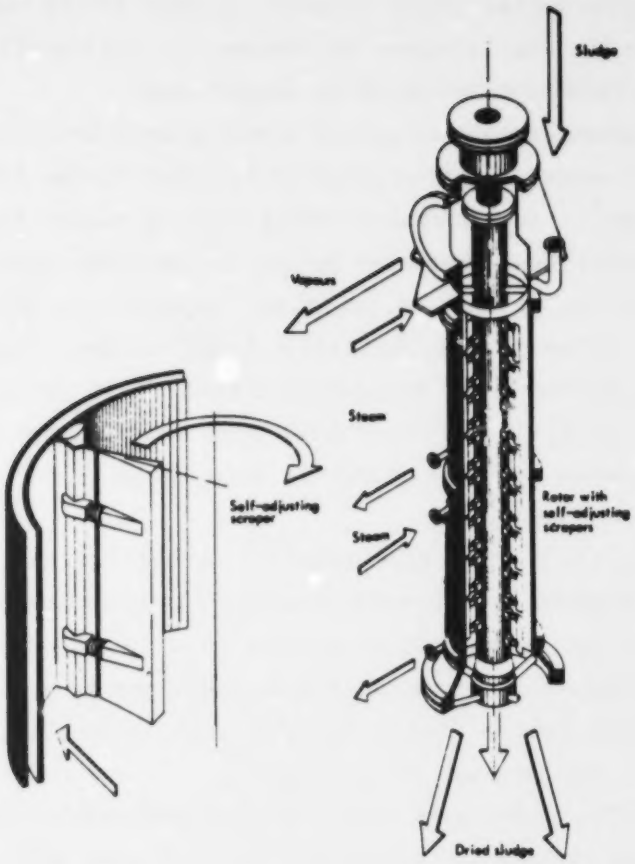


FIGURE 10-8. CUTAWAY DRAWINGS SHOWING PRINCIPLE OF LUWA DRYER (COURTESY OF VON ROLL, LTD.)

vapors, a steam-heated vapor reheater is used to dry the vapor before it is injected into the furnace. At Dieppe, a radioactive sludge feed indicator was installed but it is no longer used.

An unknown amount of excess steam is sent to a river water-cooled condenser, the condensate from which is returned to the boiler.

Krings[1] has prepared Table 10-2 in which he estimated the amount of excess heat generated by the Dieppe plant under three different rates of operation. In that calculation, no explicit allowance was made for the heat value of the partially dried sludge. That is a realistic policy for sludge having a moisture content of 40 percent or more. For although the partially dried sludge does release some heat when burned, the amount released from the sludge is not a large proportion of the total liberated in the furnace.

Table 10-3, from Eberhardt[3], shows the heat value of various raw sludges. Figure 10-9 from Eberhardt[3] shows the relation of heat value to ash and combustible content. From this, it is evident that although the combustible portion of dry sludge may have a lower heat value of up to 10,000 Btu/lb (5,555 Kcal/kg), it is usually so diluted by ash and water that the net heat value is low.

In 1973, tests were run at Dieppe, one result of which was Figure 10-10 by Krings showing the efficiency of the LUWA dryers. Three of the lowest points near the center of the figure show the results from fresh, undigested sludge. This indicates that this digested sludge was more readily dried than the raw sludge.

Some difficulty is experienced at both plants when fibrous materials clog the dryer feeding system.

TABLE 10-2. RESULTS OF CALCULATION BY KRINGS(1) OF HEAT BALANCE FOR DIEPPE PLANT

		One Furnace Lower Heat Value, 1,200 kcal/kg	One Furnace Lower Heat Value, Maximum, 2,000 kcal/kg	Two Furnaces Lower Heat Value, Maximum, 2,000 kcal/kg
Net Heat Available From Combustion	Gcal/day	35.5	68.7	171.2
Total Heat Requirement for Sludge Drying	Gcal/day	22.0	22.0	65.0
Excess Heat to Dump Condenser	Gcal/day	13.5	46.7	106.2
Equivalent Population	People		Approximately 50,000	Approximately 125,000

TABLE 10-3. APPROXIMATE COMPOSITION AND LOWER HEAT VALUE OF SOME TYPICAL RAW SEWAGE SLUDGES ACCORDING TO EBERHARDT(3)

	Ash, Percent	Water, Percent	Combustible Matter, Percent	Volatile Matter, Percent	Lower Heat Value	
					Btu/lb	Kcal/kg
Ruhr Sludge	48.2	40.0	11.8	--	1,050	583
Dry	80.3	--	19.7	14.6	2,480	1,367
Berne Sludge	21.7	55.0	23.3	--	2,770	1,537
Dry	48.2	--	51.8	24.8	6,300	3,497
Emscher Sludge	29.0	44.5	26.5	--	3,300	1,832
Dry	52.3	--	47.7	19.3	6,770	3,757
Saar Sludge	33.6	40.0	26.4	--	3,400	1,887
Dry	56.0	--	44.0	17.5	6,400	3,552
Niers Sludge	2.5	93.0	4.5	--	--	--
Dry	36.0	--	64.0	--	6,280	3,485

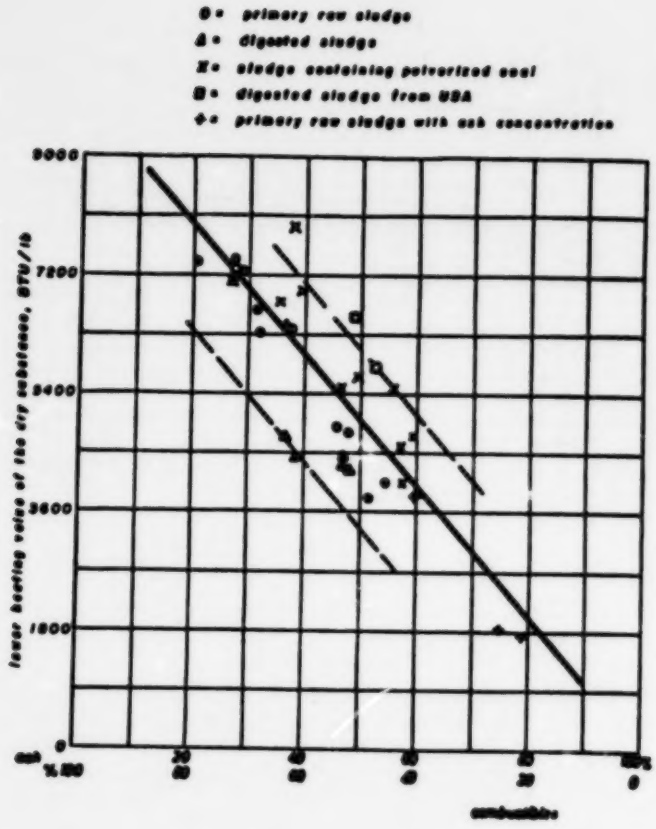


FIGURE 10-9. PLOT BY EBERHARDT[3] OF RELATION OF COMBUSTIBLE AND ASH CONTENT OF DRY SEWAGE SLUDGE TO ITS LOWER HEAT VALUE

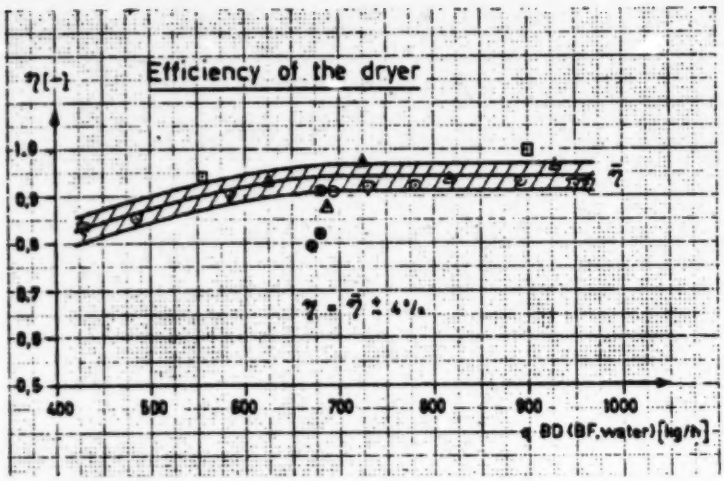


FIGURE 10-10. KRINGS(1) RESULTS OF TESTS IN 1973 AT DIEPPE ON THE EFFECT OF TYPE OF SLUDGE AND SLUDGE FEED RATE ON THE EFFICIENCY OF THE LUWA THIN-FILM DRYER

▽ Water

● Fresh Sludge - 97 Percent Water

Θ Digested Sludge - 98 Percent Water

▲ Digested Sludge - 95 Percent Water

⊡ Digested Sludge - 92 Percent Water

POLLUTION CONTROL EQUIPMENT

Flue gas dust is removed from the Dieppe gases by a vane-type 56-tube, multiple cyclone separator following each boiler built by Louis Prat of Paris. The design flow rate is 22,000 Nm^3/hr (12,947 scfm) Inlet temperature was 350 C (662 F) but after secondary air jets were added in the front wall, it dropped to 280 C (536 F). Pressure drop at 350 C is 62 mm water. Figure 10-11 shows a 155 mm diameter cast alloy vane for imparting spin to the gases entering each of 56 collector tubes in the dust collector. It is warranted to collect 92 percent of the dust, giving an emission of 400 mg/m^3 at 450 C (842 F). The initial measured emission was 320 mg/Nm^3 (0.27 lb/1,000 lb gas).

The collected dust falls continuously through a lock chamber controlled by two cam-operated cast iron flap valves into a screw which discharges it to the grate residue quench channel. The staff are well aware that failure to keep this lock chamber gas tight will allow reentrainment of the collected ash with consequent vane and tube erosion. The flap valves are serviced every 6 months to assure their tightness.

The newer plant at Deauville does not have a multicyclone but uses instead an electrostatic precipitator which has an inherently higher collection efficiency.

Chimney

At Dieppe, the chimney is 1.4 m (4.6 ft) diameter steel, unlined, reaching 35 m (115 ft) above ground. It is estimated that corrosion will require stack replacement approximately every 7 years.

Chimney construction at Deauville is the same except that a simple perforated wall muffler was added at the top because of local noise complaints.

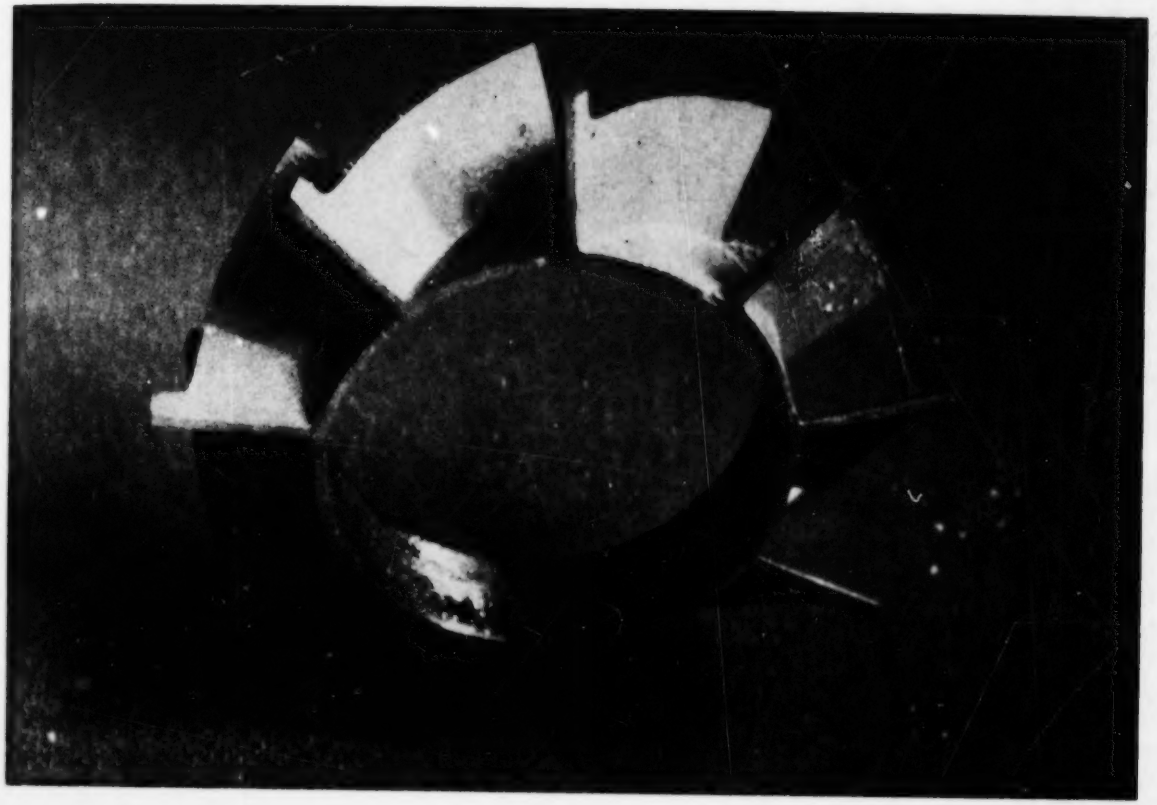


FIGURE 10-11. REPLACEABLE CAST ALLOY STEEL VANE WHICH IMPARTS SPIN TO THE GASES ENTERING EACH COLLECTION TUBE OF THE PRAT MULTIPLE CYCLONE DUST COLLECTOR (Battelle Photograph)

EQUIPMENT PERFORMANCE ASSESSMENT

The operating group, Thermical-INOR, is required by its contract with the city of Dieppe to gather and submit performance data for the refuse and wastewater plants. Tables 10-4 and 10-5 show the refuse plant results for the year 1976. The total two-furnace operating time of 6,228 hours is 35 percent based on a total of two times 8,760 hours/year. Based on a 5-1/2 day week, the operation time is 45 percent. As indicated early in this report, the Dieppe plant was sized in anticipation of considerable growth in load.

Table 10-6 summarizes the refuse plant operation over the 5 years, 1972-1976. Load and performance have been quite steady over that period.

TABLE 10-4. SUMMARY FOR 1976 OF REFUSE-SLUDGE BURNING PLANT OPERATION AT DIEPPE. TABULATION PREPARED BY PLANT OPERATORS, THERMICAL-INOR, IN FULFILLMENT OF THEIR OPERATING CONTRACT WITH THE CITY

	January	February	March	April	May	June	July	August	September	October	November	December	Total
Source and Amount of Refuse, kg													
Dieppe	826,350	751,250	879,950	871,300	893,000	889,950	963,800	914,350	839,200	864,100	855,150	826,650	10,357,050
Neuville les Dieppe	331,700	304,300	365,500	354,100	359,050	351,150	339,550	327,750	353,350	357,400	375,500	352,650	4,172,000
Roumeenil	21,400	17,850	22,850	25,950	24,100	20,400	24,450	23,950	22,500	25,850	26,100	25,550	278,450
Manehouville	1,200	1,300	1,400	800	1,100	2,150	1,200	1,600	1,400	1,200	1,150	1,850	16,350
Martigny	2,600	3,050	2,600	2,700	3,000	2,700	2,250	3,350	3,100	3,150	3,000	2,550	34,050
Crosville	1,100	1,400	900	1,200	1,050	1,100	1,250	2,050	1,500	900	1,450	900	14,800
La Chaussee	750	1,200	1,100	950	1,150	900	950	1,400	1,150	1,500	1,200	1,000	13,250
La Chapelle du Bourgay	400	500	500	550	700	600	650	700	650	500	550	500	6,600
Industrial, Commercial	156,700	149,750	144,700	123,800	123,300	136,600	125,850	62,350	127,250	112,800	116,850	158,600	1,536,350
TOTAL REFUSE, kg	1,342,200	1,230,600	1,419,500	1,383,150	1,406,450	1,403,150	1,439,750	1,336,800	1,350,100	1,367,400	1,381,150	1,370,250	16,428,700
Volume of Digested Sludge Dried and Burned, m^3	315	405	345	195	390	345	345	460	415	490	350	345	4,600
Production of Clinker, kg	666,050	568,550	612,350	550,350	488,650	677,500	608,150	582,600	568,050	594,050	636,100	617,550	7,149,750
Electrical Energy Consumed, kw	62,700	54,700	54,600	58,700	55,300	76,000	71,200	60,200	55,200	61,000	59,400	65,900	736,900
Period of Furnace Operation													
Furnace 1, hours	191	209	376	271	0	300	293	161	310	319	344	171	2,949
Furnace 2, hours	295	229	112	176	441	402	305	351	160	227	211	368	3,279
Total Furnace Operation	486	438	488	447	441	702	598	514	470	546	555	541	6,228

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TABLE 10-5. DIEPPE WASTEWATER PLANT SUMMARY FOR 1976. TABULATION PREPARED BY THERMICAL-INOR, IN FULFILLMENT OF THEIR OPERATING CONTRACT WITH THE CITY

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Wastewater treated, m^3	133,630	136,750	148,480	139,320	153,260	152,350	150,960	132,420	162,550	139,290	132,280	158,900	1,740,190
Digested sludge produced, m^3 (approx. 92% water)	315	405	345	395	390	345	345	460	415	490	350	345	4,600
Gas produced, m^3 (approx. 65% CH_4)	11,737	13,925	15,967	14,810	14,535	14,391	12,366	11,040	13,362	12.916	11,381	11,518	157,948
Chlorine used, kg	75	75	75	75	75	75	75	75	75	75	75	75	900
Electricity consumed, kWh	44,700	42,100	45,700	44,300	42,600	41,500	41,800	38,700	42.400	44,800	43,500	45,900	518,000

TABLE 10-6. ANNUAL REFUSE INCINERATOR OPERATING RESULTS FOR DIEPPE - 1972-1976 (COURTESY VON ROLL, LTD.)

		1972	1973	1974	1975	1976
Combustion						
Refuse	tonnes	17,291	18,885	19,185	18,446	16,428
Clinker and flyash	tonnes	6,702	7,265	7,359	7,298	7,149
Operating Hours						
Furnace 1	h	3,423	3,281	4,083	3,325	2,949
Furnace 2	h	3,985	3,353	4,343	3,153	3,279
Power Consumption x 1000	kWh	733	779	818	711	737
Power Consumption/t Refuse	kWh/t	42.42	41.25	42.62	38.54	44.85
Total Water Consumption	m^3	941,538	1,079,968	910,061	827,396	--
City Water	m^3	43,298	68,578	51,441	53,246	--
Industrial Water	m^3	898,240	1,011,390	858,620	774,150	--
Water Consumption/t Refuse	m^3/t	54.45	57.19	47.44	44.86	--

Note: To convert metric tonnes to short tons multiply by 1.1
To convert cubic meters to gallons multiply by 264.2

POLLUTION CONTROL ASSESSMENT

The Dieppe and Deauville plants meet the French emission limits for particulates which are on a sliding scale as follows:

Each Furnace Capacity, tons/hr	Particulate Emission, at 7% CO^2	
	mg/Nm^3	lb/1000 lb gas
Less than 1	1,000	0.83
1-4	600	0.50
4-7	250	0.21
Above 7	150	0.12

A plant operating at less than 100 tonnes/day must record only opacity. Above 100 tonnes, CO, CO_2, and O_2 must be recorded.

Compliance is established by an initial test by organizations licensed to do testing. Such groups are Apave, Socotec, or CHERCHAR, the research branch of Charbonnage de France (the Fren[illegible]reau of Mines). In addition, there is an annual plant inspection [illegible]uding examination of clinker quality and stack opacity records. At Diep[illegible]e, the opacity meter was made by Mobray.

Any wastewater from the refuse plant is sent to the adjacent sewage treatment plant. The grate residue goes to a regularly covered landfill. There is no leachate control.

There is no French regulation on plant noise. Some local areas have regulations. Dieppe has none.

Both plants are in industrial areas but are also near some residences. Figure 10-12 shows some nearby residences viewed from the roof of the Dieppe plant. Figure 10-13 shows neighboring residences viewed

FIGURE 10-12. RESIDENTIAL AREA AND COUNTRYSIDE VIEWED FROM ROOF OF DIEPPE PLANT (Battelle Photograph)

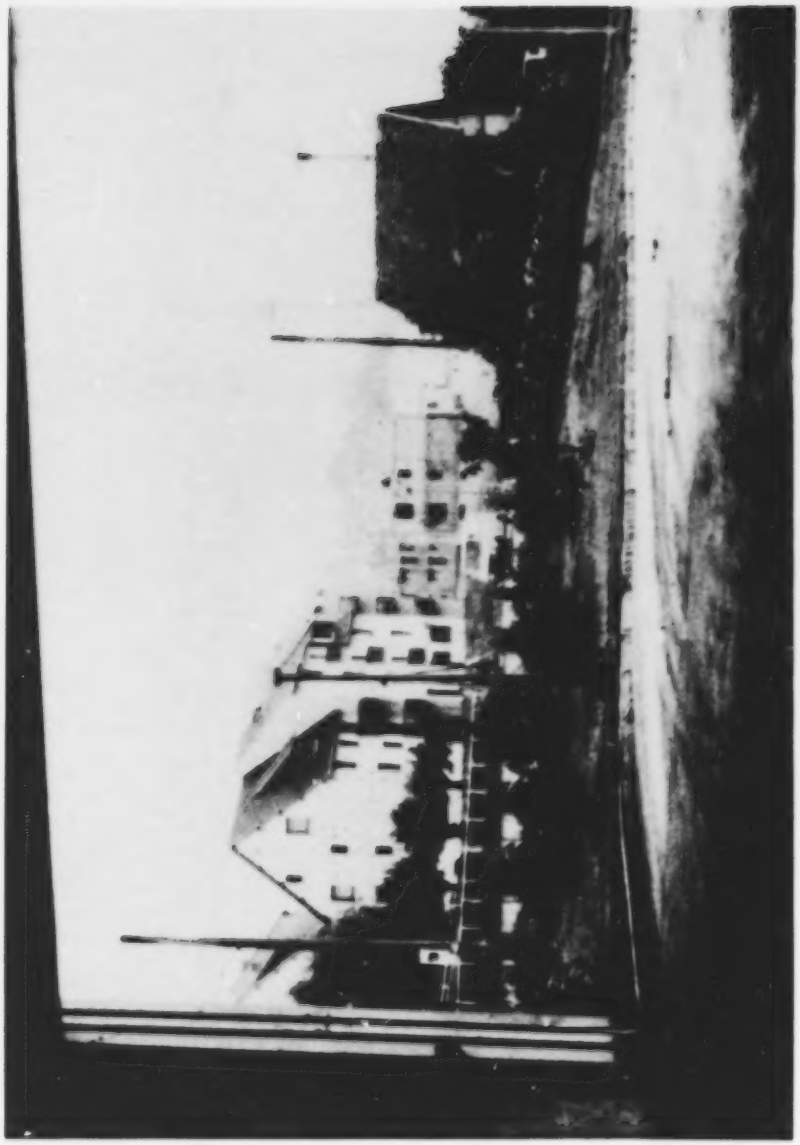

FIGURE 10-13. RESIDENCES VIEWED THROUGH TRUCK ENTRANCE AT DEAUVILLE PLANT (Battelle Photograph)

through the truck entrance of the Deauville plant. At Deauville, some noise complaints were raised; hence, a silencer was added to the top of the chimney although the noise 100 m (328 ft) from the plant was said to measure only 40 dB.

PERSONNEL AND MANAGEMENT

M. Jean Fossey, Dieppe Plant Manager, is an employee of INOR S. A. (Societe de construction d'usines, pour l'incineration des ordures menageres)(Firm for Construction of Facilities for the Incineration of Community Refuse), the Paris industrial organization which built and, along with Thermical, operates the plant for the city of Dieppe.

M. Fossey had experience in the merchant marine. His assistant manager has pressure vessel experience and can also serve as a mechanic and welder. They direct the work of 14 other staff as follows:

- Three control room and crane operators*
- Three furnace room operators*
- One electrician*
- One scale operator*
- One mechanic*
- One assistant mechanic
- Two aides (for cleaning and housekeeping)
- One driver (loads and hauls clinker)
- One wastewater plant operator
- Three furnace room operators.

Originally, the workweek was 48 hours. Now it is 42. There are usually six men on a shift. French law requires that wherever high pressure steam is used, at least two men must be on duty.

The total annual staff cost in 1976 was about 850,000 FFr ($178,500 @ 4.76 FFr/$). To this must be added social benefit costs which total about 50 to 55 percent.

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* Can also serve as shift foreman.

ECONOMICS

Capital Investment

The general contract in 1969 for building the refuse plant structure without equipment or land was for 1,532,771 FFr ($294,764 @ 5.20 FFr/$). The installed equipment raised the total refuse plant cost including the sludge dryers to 6,400,000 FFr ($1,230,769 @ 5.20 FFr/$).

From the time the tender was made in 1969 until the plant was commissioned in 1970, the final price was up about 16 to 18 percent because of inflation.

In Reference 2, M. Marchand reported that the wastewater treatment plant cost 4,980,000 FFr ($957,692). The total cost of 11,380,000 FFr ($2,188,462) was financed in 1970 as follows:

	French Francs	Dollars @ 5.2 FFr/$
State 30-Year Debentures	2,170,000	417,308
Federal Grants	3,202,528	615,871
Borrowed From National "Caisse des Depots"	5,000,000	961,538
Dieppe Tax Reserve	1,000,000	192,308
TOTAL	11,372,528	2,187,025

The loan from Caisse des Depots was a 30-year loan at 4.5 percent.

In 1971, additional purchases were made of a second crane, weigh station, furniture, ash truck, refuse containers,and workshop and tools for about 700-800,000 FFr. This money was advanced by INOR to be paid back over 20 years at an annual charge for principal and interest of 75,873 FFr ($14,591).

Operating Costs

The annual operating costs for 1976 to process 14,891 tonnes (16,381 tons) of refuse were as follows (in terms of 1976 currency):

	French Francs	Cost in $ @ 4.76 FFr/$
Payments to INOR to amortize 1971 loan	75,873	15,933
Fixed operating allowance	600,157	126,033
Proportional operating allowance up to 1,400 tonnes	282,664	59,359
Operating allowance for additional 892 tonnes	41,186	8,649
Fixed maintenance allowance	123,104	25,852
Variable maintenance allowance up to 14,000 tonnes	44,979	9,446
Maintenance allowance for additional 892 tonnes	5,041	1,059
SUBTOTAL*	1,173,004	246,331
Value added top of 17.6 percent	193,095	40,550
TOTAL	1,290,226	270,948

For 1976, this total operating cost was 86.64 FFr/tonne ($18.19 @ 4.76 FFr/$). This is higher than the original charge, 53 FFr/tonne because of inflation over the past 6 years.

For operation of the wastewater treatment plant, the city originally paid 0.24 FFr/m^3. At present, it pays Thermical-INOR 0.3189 FFr/m^3 ($0.184/1,000 gal). For the 1,740,190 m^3 treated in 1976, this came

to 554,946.6 FFr ($116,539 @ 4.76 FFr/$). Thus, the operation of the total complex cost the city 1,845,189.4 FFr ($387,490 @ 4.76 FFR/$) in 1976. A city tax is adjusted to pay these costs. The participating towns pay Dieppe in proportion to the amount of waste handled.

Revenue

Private haulers pay 110 FFr/tonne ($19.09/ton) to Thermical-INOR to deliver refuse to the plant. Of this tipping fee, 8 FFr are then paid by Thermical-INOR to the city.

REFERENCES

(1) Krings, J., French experience with facilities for combined processing of municipal refuse and sludge, Proceedings, CRE-Conference on Conversion of Refuse to Energy, Montreaux, Switzerland, November 3-5, 1975.

(2) Marchand, A., Boues d'egout + ordures = machefers (sludge plus refuse equals clinkers), Reprinted by Von Roll AG, Zurich, From T.S.M. - L'Eau, October, 1972, pp 381-391.

(3) Eberhardt, H., European practice in refuse and sewage sludge disposal by incineration, Proceedings, 1966 National Incinerator Conference, ASME, New York, May, 1966, pp 124-143.

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TABLE . EXCHANGE RATES FOR SIX EUROPEAN COUNTRIES, (NATIONAL MONETARY UNIT PER U.S. DOLLAR) 1948 TO FEBRUARY, 1978(a)

	Denmark Kroner (D.Kr.)	France Francs (F.Fr.)	W. Germany Deutsch Mark (D.M.)	Netherlands Guilders (Gl.)	Sweden Kronor (S.Kr.)	Switzerland Francs (S.Fr.)
1948	4.810	2.662	3.333	2.653	3.600	4.315
1949	6.920	3.490	4.200	3.800	5.180	4.300
1950	6.920	3.499	4.200	3.800	5.180	4.289
1951	6.920	3.500	4.200	3.800	5.180	4.369
1952	6.920	3.500	4.200	3.800	5.180	4.285
1953	6.920	3.500	4.200	3.786	5.180	4.288
1954	6.914	3.500	4.200	3.794	5.180	4.285
1955	6.914	3.500	4.215	3.829	5.180	4.285
1956	6.914	3.500	4.199	3.830	5.180	4.285
1957	6.914	4.199	4.202	3.791	5.173	4.285
1958	6.906	4.906	4.178	3.775	5.173	4.308
1959	6.908	4.909	4.170	3.770	5.181	4.323
1960	6.906	4.903	4.171	3.770	5.180	4.305
1961	6.886	4.900	3.996	3.600	5.185	4.316
1962	6.902	4.900	3.998	3.600	5.186	4.319
1963	6.911	4.902	3.975	3.600	5.200	4.315
1964	6.921	4.900	3.977	3.592	5.148	4.315
1965	6.891	4.902	4.006	3.611	5.180	4.318
1966	6.916	4.952	3.977	3.614	4.180	4.327
1967	7.462	4.908	3.999	3.596	5.165	4.325
1968	7.501	4.948	4.000	3.606	5.180	4.302
1969	7.492	5.558	3.690	3.624	5.170	4.319
1970	7.489	5.520	3.648	3.597	5.170	4.316
1971	7.062	5.224	3.268	3.254	4.858	3.915
1972	6.843	5.125	3.202	3.226	4.743	3.774
1973	6.290	4.708	2.703	2.824	4.388	3.244
1974	5.630	4.444	2.410	2.507	4.081	2.540
1975	6.178	4.486	2.622	2.689	4.386	2.620
1976	5.788	4.970	2.363	2.457	4.127	2.451
1977	5.778	4.705	2.105	2.280	4.670	2.010
1978 (Feb.)	5.580	4.766	2.036	2.176	4.615	1.987

(a) Exchange Rate at end of period.

Line "ae" Market Rate/Par or Central Rate.

Source: International Financial Statistics: 1972 Supplement; April, 1978, Volume XXXI, No. 4, Published by the International Monetary Fund.

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